Human Memory and Cockpit Operations: An ASRS Study

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Key Dismukes

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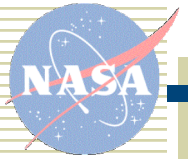
Northwest Flight 255

- Crashed shortly after takeoff
- Caused by "the flightcrew's failure to use the taxi checklist to ensure that the flaps and slats were extended" (NTSB, 1989)
- Safeguards normally would have caught error - checklists, warning system
- Likely that the number of errors that occur without incident is much greater.

Why do memory errors occur in the cockpit?

- Should we assume that pilot errors are due to lack of training/skill/discipline?
  - Pilots of 255 did forget checklist
- We believe vulnerability to memory errors is a function of normal human memory processes within situations involving routine, well learned behaviors.



Current Study

- How frequently do memory errors occur in the cockpit?
- What kinds of memory errors occur in the cockpit?
- Where are the vulnerabilities?
- What countermeasures can help reduce these vulnerabilities?

Method

- Extracted 20% of Part 121 ASRS reports dated 2001 - total of 1299 reports
- Each report was read and determined to be a memory or non-memory error
- Reports indicating memory failures were categorized

Categorization Process

- Sorted by primary cause/type of error
  - Necessarily involved guessing
- More general categories emerged based on our knowledge
  - Retrospective vs. prospective
  - Roles of attention and cueing
- Categories overlap
  - Processes are interwoven

Retrospective Memory

- Process of retrieving facts or procedures
  - Remembering where I parked my car
  - Remembering how to knit a sweater
- Much of the variance due to experience
  - Deep learning = low memory failure

Prospective Memory

- Process of retrieving goals from memory - *at the moment that they can be performed*
  - Remembering to bring lunch to work
  - Remembering to attend a meeting
- Variance in performance due to
  - Cueing
  - Attention

Prospective Memory - Cueing

- Cue
  - Reminder that facilitates retrieval and initiation of a goal
  - Must be be highly associated to the intention - high probability of calling the intention to mind when it is noticed.
  - Must be salient - high probability of being noticed *at the time that the intention must be performed*

Prospective Memory- Attention

- Attentional resources are required when cues are less likely to automatically capture attention
- The more attention we direct to a cue, the more likely we are to recall the associated intention

Results

- 105 memory errors reported
- 75 (6%) involved errors by pilots
  - 1 retrospective memory error
  - 74 prospective memory errors
    - Failure to monitor 19 (26%)
    - Absence of adequate cues 27 (36%)
    - Habit capture 14 (19%)
    - Poorly formed intentions 14 (19%)

1. Failure to Monitor

- 26% forgot to monitor for the appropriate moment to perform an intention
  - course deviation - altitude bust or a failure to make a crossing restriction
- Attention processes are central
- Initiating and maintaining monitoring also involves memory retrieval

1. Failure to Monitor

Shortly after takeoff...the flight director failed, followed by the flight guidance panel going totally inop...The captain (pilot flying) asked me to switch flight director to 'both'...while I was locating and changing the position of the switch we passed through our clearance altitude... (Accession # 486880).

2. Absence of adequate cues

- 36% indicated a lack of adequate cues
- Cockpit operating procedures generally provide consistent, highly effective cues
- When routine changes - those cues are no longer available - pilots become vulnerable to forgetting to perform the task

2. Absence of adequate cues

- 13 (18%) involved landing without clearance
- In all but one, crew failed to contact tower

  We landed and taxied clear of the runway. However, apparently the FO had not received a clearance to land. Our radio was still on the approach frequency (Accession # 493970).

2. Absence of adequate cues

- Why is LWOC so common?
- Not due to lack of experience
- Perhaps due to instructions from ATC

Approach told us to switch to tower at the final approach fix (Accession # 472320).

Clearance was to …contact tower at the marker (Accession # 468770).

2. Absence of adequate cues

- Typically, approach control directs crews to switch to tower immediately
- Reports describe salient, but ill-timed cues
- We are vulnerable to forgetting even when delay is only a few seconds (Einstein et al., 2000)
- Most crews remembered upon landing - salient cue for contacting ground

2. Absence of adequate cues

- 6 (8%) reported failure to reset the altimeter when passing through 18,000 feet
- Can result in significant altitude deviations
  - One report involved a subsequent TCAS alert

2. Absence of adequate cues

- Why forget to set the altimeter?
- 18,000 feet is highly associated with task - should improve memory
- However, cue is not salient
  - Altimeters provide the only direct cue to reaching 18,000 feet
  - But altimeters do not demand attention at 18,000 feet

2. Absence of adequate cues

- Monitoring is involved when cue is less salient
- Other activities routinely performed may remind the pilot to monitor for 18,000 feet
- When that monitoring is disrupted the pilot becomes vulnerable to forgetting.

> *It was moderately turbulent during our descent…. We were distracted at this time and failed to reset our altimeters to the new…setting* (Accession # 468640).

3. Habit Capture

- 19% involved performing a habitual task instead of the intended task
- Overlearning protects habitual actions but also creates vulnerability to error - behavior often initiated automatically
  - Task overload
  - Fatigue
  - Interruption

3. Habit Capture

- Failure to modify habitual task

Our error was continuing on J174 past ZIZZY toward SWL…. We fly J174 to SWL 3-4 times per week and simply forgot we had received a change to our planned flight plan (Accession # 487740).

3. Habit Capture

- Familiarity creates vulnerability
- Flow of events is highly associated with the habitual flight path not with atypical plan
- In contrast, no salient cues to remind the pilots to follow the new clearance
- In highly familiar situations people tend to respond automatically with habitual actions
  - Less monitoring for cues

3. Habit Capture

- Failure to interrupt habitual task

Departed…with open logbook item.
Departed early and in the last minute forgot the item was not signed off by maintenance
(Accession # 474050).

3. Habit Capture

- Forgetting to inhibit routine flow
- Each step strongly triggers the next step
- No cues in normal procedures to effectively prompt non-routine tasks
- Active monitoring can reduce vulnerability to forgetting
  - However, monitoring requires attentional resources which are limited

4. Poorly formed intentions

- 19% of errors
- Successful retrieval of a new intention relies on encoding - associating task with cues
  - Can be done mentally or by creating a physical cue (tying a string around one's finger)
- May be especially critical in the cockpit - new intentions often compete with highly practiced tasks

4. Poorly formed intentions

- Failure to encode explicitly

We began taxiing to runway 28.... Ground control informed us runway 28 was now closed and to make a 180 degree turn back to runway 24R.... When reaching the departure end of 24R, we were cleared for takeoff. At 400 feet…heading select [was] incorrect for runway 24R, but correct for runway 28, our original runway (Accession # 494810).

4. Poorly formed intentions

- Old intention in a new context
- Intention is implicit - general intention to set heading selector before takeoff
- Intention to set heading selector while taxiing to new runway was not explicit
- Normal flow provides good cues for remembering - cues gone in new context
- Retrieval is left to chance reminders without explicit identification of potential cues

4. Poorly formed intentions

- Poor cue selection

Turned on both center pumps to deplete approximately 800 pounds [of fuel]. Started clock to estimate time to turn off pumps. Briefly discussed maximum altitude aircraft was capable of obtaining with moderate turbulence…. After verifying flight level 410 was acceptable looked up and noticed the center tank fuel had just reached zero pounds and turned off pumps (Accession # 469100).

4. Poorly formed intentions

- Not all cues are good cues
- Reporter recognized the need to find a cue
- Clock was not an effective reminder
  - Associated with the intention
  - But did not draw attention at the moment when the intention should have been performed.
- Clock would have been effective with an alarm - would not have escaped notice

Summary

- Prospective memory errors comprise the majority of pilot memory failures reported
- 4 categories of error all based on 2 basic factors
  - Cue effectiveness
    - Must be highly associated to the intention - high probability of calling the intention to mind when it is noticed.
    - Must be salient - high probability of being noticed ***at the time that the intention must be performed***
  - Monitoring
    - The more attention we direct to a cue, the more likely we are to recall the associated intention

Potential Countermeasures

1. Recognize non-routine situations
   - Interruptions, deviations from habitual actions, deferred tasks
2. Stick to established operating procedures as much as possible
   - These provide safeguards against forgetting
3. Recognize monitoring as a critical task